Alberta Scientific and Engineering Services

Studies of Fine Coal Cleaning and Upgrading Processes for Alberta Coals

Projects supported in part by the Alberta Canada Energy Resources Research Fund

ALBERTA
OFFICE OF
COAL
RESEARCH

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal and conventional energy resources, as well as energy conservation and renewable energy. Program administration is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In recognition of the importance of coal to Alberta's economy, the Alberta Office of Coal Research and Technology was established in 1984 within Alberta Energy and Natural Resources (now Alberta Energy). Its primary purpose is to encourage the development and application of new technologies related to Alberta coals. The Office provides funding contributions to research and development projects in industry, academic institutions and other research establishments and monitors their progress in an overall program of improving the production, transportation and marketability of Alberta coals.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page 10.

Studies of Fine Coal Cleaning and Upgrading Processes for Alberta Coals

As the international coal market has become more competitive, coal producers have responded by lowering their operating costs and experimenting with ways to recover more specification-grade coal from the raw coal handled by their preparation plants. In Alberta, much of this effort has involved attempts to recover more coal fines.

Concurrently, modern fuel standards have become more stringent in response to environmental requirements and the availability of new or improved combustion technologies. As a consequence, coal researchers world-wide have begun to develop methods to upgrade coal into products that have been energy-enhanced or produce fewer sulphur oxides when burned.

A broad range of investigations covering some aspects of fine coal recovery and coal upgrading is being pursued in Alberta. Included are studies aimed at recovering more fines in the form of economically valuable products, and upgrading bituminous and subbituminous coals to enhance their energy content and combustion performance characteristics. Several of these investigations were supported in part by the Alberta/Canada Energy Resources Research Fund (A/CERRF). They are described here.

Recovery of Coal from Tailings

Typically, 70 per cent of any run-of-mine coal from western Canada is of the quality specified by international or central Canadian customers. The 30 per cent that is not specification-grade includes particles that are an admixture of carbonaceous and shaly materials. Although these particles (called "middlings") could be separated from the remainder, which is true refuse, it would not be economic to transport middlings to out-of-province users. Also, these coals contain a substantial fraction of particles smaller than 0.6 mm in diameter. These "fines" represent one-third of the mass of a typical western Canadian coal and they are more difficult than coarser coal to separate accurately into specification-grade coal, middlings and refuse.

Similar difficulties are encountered in product dewatering systems. The substantial quantity of rejected fines (called "tailings") contains fine refuse, middlings and some misplaced specification-grade coal. The coarse process rejects are dewatered readily and disposed of as a solid waste. Tailings, however, present a costly disposal problem. They emerge suspended in the cleaning process water. Generally, a thickener permits immediate recycle of clarified water to the process plant. The thickener underflow may undergo mechanical dewatering to reduce the volume further. Invariably, settling ponds are employed for environmentally safe disposal.

In 1987/88, in a project carried out by the Coal Mining Research Company (CMRC), a review was made of optional methods that might be considered in schemes to recover coal from tailings. The objectives of the project were to ascertain whether it was economically feasible to:

- salvage fine coal from preparation plant tailings;
- dewater and dispose of the true refuse in a more acceptable manner than storing it in lagoons; and
- use water resources more efficiently in coal washing.

Available literature from around the world was reviewed on more than 30 processes that might be considered for coal recovery, tailings dewatering, tailings disposal and waste water management. The final report provides a comprehensive overview of the state-of-the-art on this subject.

Several conclusions were drawn from this investigation. For example, it was stated that perhaps two per cent of specification-grade coal is lost with tailings. The most probable route for successful recovery of coal currently lost to tailings requires segregation of plant water flows into low- and high-ash circuits for separate and subsequent treatment.

It was concluded that some devices warrant further consideration and experimentation with Alberta coals. They include fine coal separators such as:

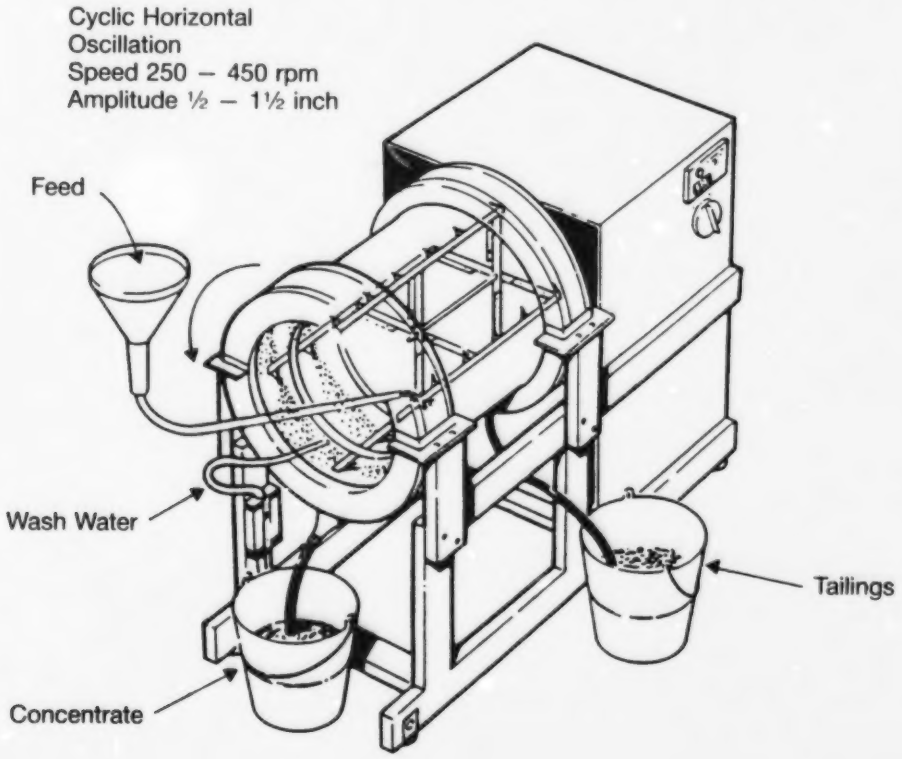
- spiral separators;
- the Linatex HYDROSIZER;
- the Multi G Separator; and
- several types of flotation devices.

Also recommended for additional study were several types of dewatering equipment and processes, such as:

- KHD Hyperbar and AMA pressure filters;
- the Rapid Sludge Dewatering System;
- the U.S. Bureau of Mines dewatering technique; and
- the Delcor Linear screen.

Several additional conclusions resulted from this study. It was stated that upgrading of substandard coal is unlikely to be economic because current upgrading costs exceed the costs of mining equivalent coal.

Multi G Separator

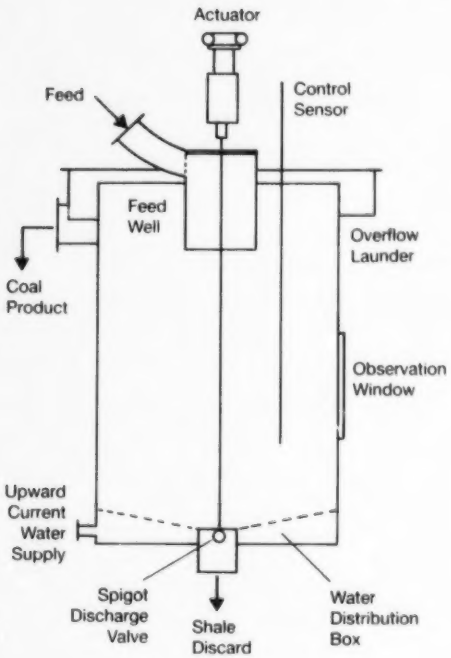


(Source: Recovery of Coal from Tailings, Butcher, S.G. and A.L. Craven, Coal Mining Research Company, June 1988)

Long-term experience indicates that the costs to purchase, operate and maintain tailings dewatering equipment are higher than the costs of tailings ponds. Filtered water discharged from a coal cleaning plant does not pollute the environment.

Recovery of 10 per cent of the as-mined heating value of middlings could provide a significant heat source for power generation or industrial steam generation.

Linatex HYDROSIZER



(Source: Recovery of Coal from Tailings, Butcher, S.G. and A.L. Craven, Coal Mining Research Company, June 1988)

Froth Flotation Study at Coal Valley Mine

Currently, Alberta producers of bituminuous thermal coal discard the high ash fines portion during washing because of difficulties caused by the presence of colloidal clay. This reduces the yield and affects the overall ash content of the cleaned products.

Based on encouraging results from previous coal flotation experiments carried out by Luscar Sterco (1977) Ltd., operators of the Coal Valley mine, a decision was made to contract the services of the University of British Columbia, the University of Alberta and the Coal Mining Research Company to study the flotation properties of three fine coal streams from the mine. The objective was to develop a process of economically producing a clean coal product having an ash content of 12 per cent.

The tests included evaluation of fines circuit losses and pilot-scale testing of conventional flotation technology and emerging column flotation techniques.

Experimental results were widely variable, making it difficult to draw any firm conclusions. It was estimated that a 12 per cent ash content could be achieved, but only at a 16 per cent yield. This is uneconomic.

Because of these results, it was decided not to proceed with larger scale trials. The study did demonstrate, however, that more research is needed to define the parameters controlling coal flotation behaviour and develop more suitable techniques for improving the application of flotation to fine coals having a high clay content.

Agglomeration of Coking Coal

Metallurgical coal currently being mined at Smoky River Coal Limited contains 40 per cent fines. Furthermore, coals expected to be mined in the future have a fines content as high as 50 per cent. While froth flotation is being used to recover the fines, this circuit currently limits the throughput capacity of the plant. The recovered product can be dusty and difficult to handle.

Consequently, the company experimented with an oil agglomeration process (developed by the National Research Council, NRC) as a fines-recovery method. In laboratory tests, it was found that recovery rates were higher than for froth flotation, and the product appeared to have improved handling characteristics.

Subsequently, the company and NRC decided to evaluate the potential of the NRC oil agglomeration process using the NRC mobile pilot plant at the mine site.

Two different coal feeds were evaluated in these tests. One was the -100 mesh raw coal feed to the existing flotation circuit which comprises approximately 18 per cent of total plant feed. The second was the -28 mesh thickener underflow containing typically 40 per cent ash.

Up to 90 per cent yields of coal were obtained from the -100 mesh feed, using oil concentrations ranging from 0.7 to 12 per cent. Coking properties were unaffected. Up to 61 per cent of the coal from the thickener underflow was recovered. With this material, ash content was reduced from 41 to 20 per cent.

An economic analysis revealed that oil agglomeration was somewhat more expensive than conventional froth flotation; however, agglomeration could become competitive if the amount of added oil can be kept at or below one per cent by weight, or capital costs for agglomeration facilities can be reduced.

Fine Coal Cleaning Technical Committee

In recognition of the problems caused by coal fines, a Fine Coal Cleaning Technical Committee[1] was established in 1988 to provide a method for co-ordinating and funding research efforts. The creation of this committee was given impetus in November 1987 by the report of the Intergovernmental Secretariat to the Action Committee on Western Canadian Low Sulphur Coal to Ontario, which recommended that Alberta should take the lead role in initiating research on fine coal cleaning.

[1]Committee members on July 31, 1989 were: Obed Mountain Coal Company Limited, Gulf Canada Resources Limited, Fording Coal Limited, Luscar Sterco (1977) Ltd., Westar Mining Ltd., Esso Resources Canada Limited, Smoky River Coal Limited, Gregg River Resources, Quintette Coal Limited, Canada Centre for Mineral and Energy Technology (CANMET), Energy, Mines and Resources Canada, British Columbia Mines, Energy and Petroleum Resources, Saskatchewan Energy and Mines, and Alberta Office of Coal Research and Technology, assisted by the Coal Mining Research Company.

The objectives of the technical committee are:

- to find ways to reduce the delivered cost of coal in Ontario by improving fine coal cleaning, while maintaining coal quality at its current level;
- to achieve fine coal recovery so as to satisfy concerns about environmental and resource exploitation efficiency, while reducing tailings disposal costs; and
- to develop fine coal products that are acceptable to existing or potential markets.

Topics to be considered for research efforts include:

- Fines Processing
  - Utilization
  - Coal Surface Properties
  - Flotation Techniques
  - Yield Improvement;
- Ash Reduction
  - Separation by Size/Specific Gravity
  - Chemical Change/Oxidation/Storage
  - Process Automation
  - Ash Surface Properties; and
- Refuse Reprocessing
  - Tailings and Reclamation
  - Slack Pile Reclamation
  - Environmental Considerations.

Thus far, the following projects have been initiated and/or supported by members of this committee:

- Air-Sparged Hydrocyclone;
- HYDROSIZER for Fine Coal Recovery from Tailings;
- Low Cut Point Spiral;
- Tailings Reclamation;
- Laboratory-Scale Split Flotation; and
- Electrocoagulation.

The initial evaluation phase of most projects is expected to be completed in 1989/90.

Advanced Processes for Low-Rank Coal

In 1987, CMRC published a state-of-the-art review of coal upgrading processes which might enable low-rank coal to be exported from Alberta and used as fuel in conventional thermal power plants or in new or emerging coal-use technologies. In considering these potential processes, it was recognized that several inherent properties of subbituminous coals must be changed before they can compete with bituminous coals. For example, subbituminous coals have high ash, oxygen and moisture contents and low heating values. Although mining costs are low, this economic advantage would be lost if subbituminous coals were transported the same long distances to markets as bituminous coals. This is simply because transportation costs per unit of energy are higher for subbituminous than bituminous coals.

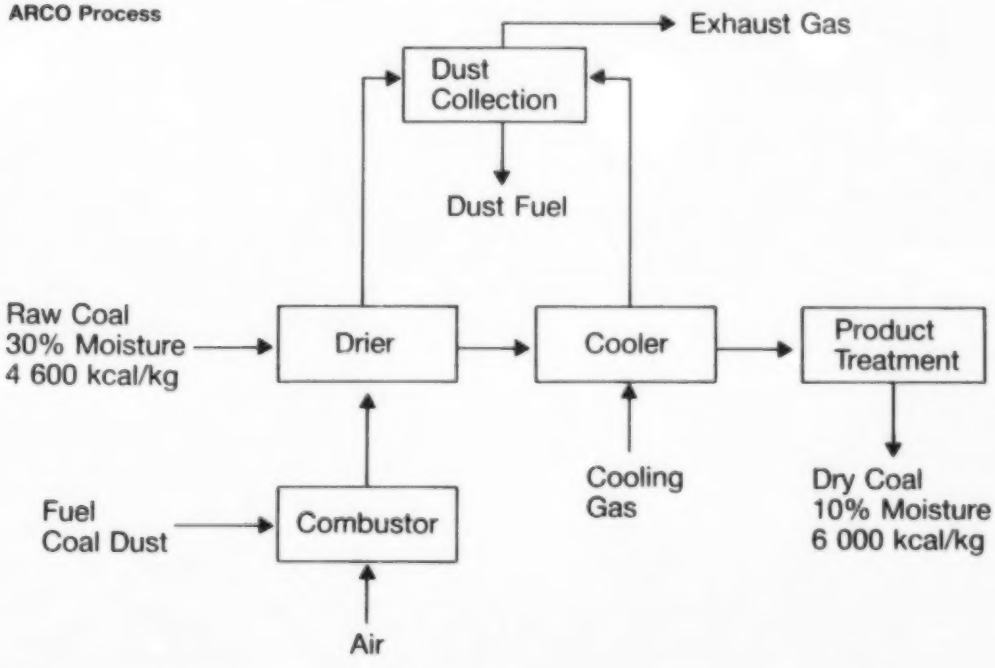
Conventional methods for cleaning western Canadian coals having high clay contents are relatively ineffective in reducing the ash content of subbituminous coal. Drying to reduce the moisture content makes subbituminous coal more susceptible to spontaneous combustion and can cause severe dusting problems when the coal is handled.

Consequently, several coal research organizations are developing methods of upgrading and stabilizing low-rank coals to overcome the deficiencies of current coal-drying and coal-washing techniques. Also, several coal-use technologies are being developed that can use low-rank coal as a feedstock.

From a survey of the literature, upgrading technologies were divided into several categories and seven processes were selected for detailed examination. They were:

- Anaconda Coal Drying Process (now known as the ARCO Process);
- Western Energy Company Advanced Coal Cleaning Process;
- Pelletizing Processes (several);
- Saskatchewan Power Corporation Upgrading Process;
- University of North Dakota Hydrotreating Process;
- K-Fuel Pyrolysis Process; and
- Oil Agglomeration Processes (several).

ARCO Process



(Source: Review of Advanced Processes for Low Rank Coal Literature Survey, Adamson, D.G., M.J. Kramer and D.F. Long, Coal Mining Research Company, December 1987)

From this review, it was concluded that the ARCO Process cannot be used to upgrade Alberta's subbituminous coals to a satisfactory level, but the cooling and deactivation stages of the process might be useful in existing coal preparation plants. It was recommended that these two stages be evaluated for coals dried below their equilibrium moisture content.

The Advanced Coal Cleaning Process developed by Western Energy Company was judged capable of upgrading Alberta subbituminous coal to a calorific value in excess of 6 000 kcal/kg, but the process needs to be controlled within narrow limits. Also, the product is dusty, although it can be stabilized to prevent moisture reabsorption and to reduce susceptibility to spontaneous combustion. It was recommended that three representative Alberta coals be tested in the drying and stabilization stages of this process.

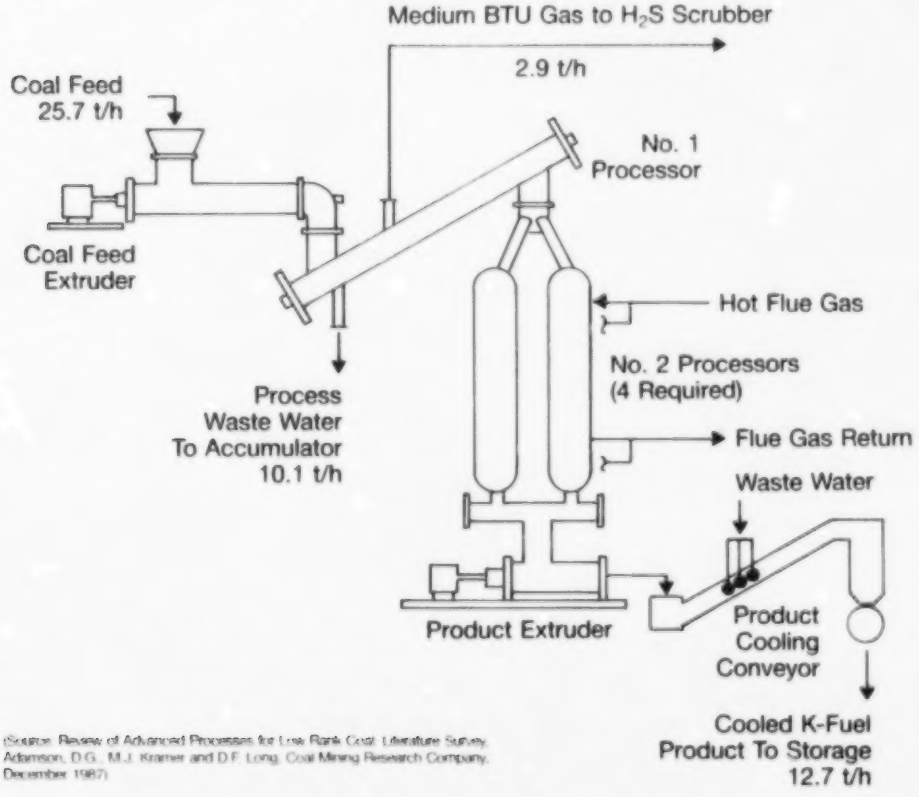
It was noted that a pelletizing process demonstrated at the Colorado School of Mines Research Institute is promising and should be developed with emphasis on a greater degree of drying.

The major advantage of the hydrotreating process developed at the University of North Dakota is its ability to produce either a solid fuel or a coal-water fuel without deep cleaning and tailings disposal stages. The process is expensive, however.

It was concluded that the K-Fuel Process achieves the highest degree of upgrading of all the processes, and a sizeable body of reliable data has been generated from pilot-scale testing. It was recommended that three typical Alberta coals be tested in this process, particularly because of its ability to produce high-calorific value fuels for specialist markets.

In general terms, oil agglomeration of subbituminous coal was rated as having the potential to meet all the requirements of a low-rank upgrading process. It was concluded, however, that the commercial viability of oil agglomeration depends on development of a method to recover oil from the agglomerates.

K-Fuel Pyrolysis Process



(Source: Review of Advanced Processes for Low Rank Coal: Literature Survey, Adamson, D.G., M.J. Kramer and D.F. Long, Coal Mining Research Company, December 1987)

Coal Beneficiation Process

In a multi-year project carried out by Gulf Canada Resources Limited and Unocal Canada Limited, a patented Gulf process for treating coal was used to upgrade the energy content of low-rank coals and make them suitable for shipping. The process involves thermal treatment of the coal by immersing it in a low-cost residual petroleum product. The hot residuum (which resembles road asphalt) drives moisture out of the coal and is absorbed into the coal voids while also coating the surface of the coal particles. In addition, the process improves the handling properties of the coal and eliminates dust problems. Residuals derived from heavy oils and bitumen found in large quantities in Alberta are particularly suitable for this process.

The process was tested extensively in batch and continuous, bench-scale equipment built for this purpose. In the batch-processing mode, coal immersion and recovery were successful. The residual moisture level was reduced to one per cent, while the equilibrium moisture level was reduced to five to eight per cent. Removal of residuum to below five per cent product weight was unsuccessful in continuous operations, however, which made the process expensive. An alternative, simple beneficiation process employing oil injection, was developed and applied successfully.

Testing showed that the revised process:

- causes the calorific value of coal to increase (with Obed coal, the calorific value was approximately 6 400 kcal/kg);
- permits controlled addition of petroleum residuum; and
- essentially eliminates dusting and handling problems.

A conventional drum mixer asphalt plant was used in a mine-mouth pilot demonstration of the process. Approximately 4 000 tonnes of Obed coal were processed at feed rates varying from 50 to 140 tonnes an hour. It was found that the feed coal could be dried to less than one per cent residual moisture, and an equilibrium moisture reduction of 65 per cent was possible. The product, however, was susceptible to autogenous heating. This was unexpected from earlier work; for example, four 200-tonne stockpiles heated rapidly after storage for two weeks.

Subsequent investigation revealed this storage instability was apparently caused by large differences in equilibrium and residual moisture levels. Laboratory evaluations of moisture and oxygen sorption confirmed that the upgraded product is more reactive than the parent coal and a stabilizing process or agent would be needed to make the process commercially viable.

After optimized process conditions were established to satisfy a set of 96-hour heating and oxygen adsorption criteria, bench-scale mixing equipment was modified to allow increased residence time, product cooling, improved feed capacity and installation of monitoring equipment. Two tonnes of beneficiated product were stockpiled and tested for stability.

Also, the effects of primary process variables such as temperature, residuum content and residence time were studied. Temperature was found to be the most important factor in reducing equilibrium moisture. Some secondary process variables were studied, too. The knowledge learned in these tests was used to develop a two-stage, continuous pilot plant. It was used to test certain process variables on a larger scale and produce sufficient quantities of treated coal for stability testing and stockpile monitoring. From these tests, it was found that the upgraded product remained less stable than the untreated feed coal.

It was concluded that the Gulf Canada Beneficiation Process offers potential for thermal coal upgrading. Even though product stability is a concern, stockpile monitoring showed that a rapid oxidation period was followed by a period of temperature stability. This suggested that stockpile management was a likely solution to the instability problem.

Low-Rank Coal Upgrading Technical Committee

In 1988/89, a Low-Rank Coal Upgrading Technical Committee was formed under the leadership of Saskatchewan Energy and Mines. The committee comprises approximately 20 members representing Alberta and Saskatchewan coal producers, governments and coal research agencies, as well as the Ontario and federal governments. The principal objective of this group is to formulate a strategy for developing an upgraded product from western Canadian low-rank coals, which would be suitable in the Ontario market.

The committee met several times during 1988/89 and agreed that coal drying and stabilizing were of greatest interest to the members. Currently, the committee is supporting:

- tests of ARCOFLUX 130 deactivant. This is a method of treating a dried coal to prevent moisture resorption and spontaneous combustion. It also limits dust problems during transport and handling;
- the collection of data on the changes to low-rank western Canadian coals during thermal drying/upgrading; and
- the development of a set of stability criteria for dried/upgraded coals.

Further Reading

Adamson, D.G., M.J. Kramer and D.F. Long. 1987. Review of Advanced Processes for Low Rank Coal: Literature Survey. Coal Mining Research Company Report PO 8669-1.

Butcher, S.G. 1987. Review of Advanced Processes for Low Rank Coal: R&D Facilities Visits. Coal Mining Research Company Report PO 8669-2.

Adamson, D.G. and S.G. Butcher. 1987. Review of Advanced Processes for Low Rank Coal: Final Report. Coal Mining Research Company Report PO 8669-3.

Butcher, S.G. and A.L. Craven. 1988. Recovery of Coal from Tailings. Coal Mining Research Company Report PO 8762.

Latimer, R.C., D. Miller and R. Seddon. 1988. Froth Flotation Study. Luscar Sterco (1977) Ltd.

Anon. 1988. SRCL/NRC Oil Agglomeration Project: Final Report. Smoky River Coal Limited.

Contacts

For more information about the recovery of coal from tailings and advanced processes for low-rank coal, contact:

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Non-proprietary information about the Gulf Canada Beneficiation Process is available from:

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Additional copies of this publication are available from:

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Other publications in this series that deal with coal research include:

An Economic Analysis of Coal Pipeline Systems, 6 pages, January 1987. (Out of print.)

Opportunities to Use Coal in Enhanced Oil Recovery, 8 pages, April 1988.

Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals, 14 pages, June 1988.

Gasification of Western Canadian Coals, 14 pages, June 1988.

Coal Research Centre, Devon, 10 pages, August 1988.

Co-processing Studies of Alberta Subbituminous Coals, 14 pages, December 1988.

Mathematical Modelling of Automedium Cyclones, 10 pages, January 1989.

The Technical Committee Approach to Coal Research, 6 pages, January 1989.

Advanced Coal Mining Techniques for Alberta, 10 pages, March 1989.

Some Combustion Studies of Alberta Coals, 13 pages, May 1989

Gasification of Alberta Coals, 10 pages, June 1989.

Development of Clean Coal Technologies for Alberta, 12 pages, July 1989.

Coal Preparation Research in Alberta, 22 pages, September 1989.

Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery 8 pages, October 1989.